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Soil washing potential at confined disposal facilities

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The diminishing capacity of existing confined disposal facilities (CDFs) is a significant operational concern, as land development and acquisition costs continue to rise. Alternatives such as capacity expansion and restricted use (that is, storage of only the most contaminated sediments or sediment fractions) have been considered for extending the life of CDFs.

Some U.S. Army Corps of Engineers' facilities are evaluating the reclamation of clean dredged material fractions from existing CDFs to recover storage capacity. This clean material has a market value, as fill or as a soil amendment, which helps offset the recovery costs.

Several low-cost alternatives exist for clean sediments, including beneficial uses and open-water disposal. However, for sediments with high amounts of contaminants, the only option that has traditionally been available has been placement in CDFs.

Through 1992, about 36 million cubic meters of material dredged from Federal projects in the Great Lakes had been contained in the 26 Federally funded CDFs authorized under Public Law 91-611. All but two of these CDFs are scheduled to be filled by the year 2006.

Contaminants often associate with a particular sediment fraction. Therefore, physical separation processes, which are the "workhorses" of the mineral processing industry, have application potential for recovering clean dredged material fractions from fine-grained or contaminated sediments.

This separation process, called soil washing, is based on the differences in particle properties— size, density, and surface chemistry. The characteristics of the sediment (particularly particle size distribution) and the manner in which the contamination is distributed will affect process choices and the efficiency of separation (Brown and Heywood 1991, Svarovsky 1990, Averett and others 1990).

The suitability of a sediment for a proposed beneficial use is determined by the physical and chemical characteristics of the sediment and the corresponding requirements of the identified use and applicable regulations.

In some cases, the acceptable physical and chemical parameters are subject to interpretation. Suitability is influenced by engineering requirements, biological sensitivity to residual contamination levels, and public acceptance. No single set of criteria can be established to satisfy the requirements of all potential uses.

To further evaluate the dredged material washing procedure, field demonstrations were conducted at the Erie Pier and Saginaw Bay confined disposal facilities.

Erie Pier demonstration

The U.S. Army Engineer District, Detroit, maintains an extensive navigation channel in Duluth-Superior Harbor in Minnesota and Wisconsin. Duluth-Superior Harbor has been designated by the International Joint Commission as one of 43 Areas of Concern in the Great Lakes Basin, due at least partially to contaminated sediments.

Detroit District operates and maintains the Erie Pier CDF (approximately 332,000 square meters) in Duluth to handle the sand, silt, clay, and organic material dredged from the harbor (more than 76,000 cubic meters annually).

In 1988, a simple dredged material washing procedure was implemented at Erie Pier on a trial basis. The objective of the demonstration was to evaluate the feasibility of recovering the sand fraction for use as construction fill, thus reducing the volume of dredged material to be stored.

Because discharge of water from the CDF is not permitted, sediments are mechanically dredged and placed in the CDF to minimize the volume of water introduced. Years of filling had resulted in a sloping surface on the CDF, with the highest elevation near the off-loading site and the opposite side under 0.9 to 1.2 meters of ponded water.

For the washing experiment the dredged material was off-loaded in a catchment area, and water drawn from the pond was pumped over the dredged material to create a slurry. The slurry was allowed to flow down a sluiceway constructed from previously dredged material. Heavy particles settled out in the sluiceway, while fines were carried down into the ponded area. The sand was recovered from the sluiceway with a front-end loader and stockpiled for testing (Figure 1) to determine its suitability for beneficial use.

During the dredging operation, the dredged material being off-loaded from scows and the washed material being stockpiled were both sampled. Samples were analyzed for particle size, organic indicators, nutrients, polychlorinated biphenyls (PCBs), and metals (arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc).

Characteristics of the dredged sediment and the washed material are compared in Table 1.

The testing conducted in 1988 demonstrated that the washed material was suitable for use as construction fill. As a result of this monitoring, the washed material is no longer required to undergo extensive testing before it can be removed from the CDF. Rather, it must only meet the criterion for use as fill (<15 percent fines).

The soil washing process has now been incorporated as a contractual requirement of the Erie Pier dredging operation and is

Figure 1. Recovery of coarse sediment (left photo) and stockpiling (right) at Erie Pier CDF soil washing project

Table 1. Characteristics of Dredged Sediment and Washed Materials at Erie Pier CDF

Parameter	Unit	Dredged Material (Avg.)	Washed Material (Avg.)	Percent Reduction
Total solids	%	55.0	86.0	NA
Silts/clays (passing No. 200 sieve)	%	69.0	14.0	80
Total volatile solids	%	2.81	0.58	79
PCBs	mg/kg	0.10	<0.02	>80
Oil & grease	mg/kg	762	263	65
Total organic carbon	mg/kg	19,300	2,206	89
Arsenic	mg/kg	1.64	0.866	47
Cadmium	mg/kg	2.98	1.10	63
Chromium	mg/kg	31.7	10.3	68
Copper	mg/kg	32.6	22.0	33
Iron	mg/kg	22,200	7,220	68
Lead	mg/kg	65.2	17.4	73
Mercury	mg/kg	0.108	0.0136	87
Nickel	mg/kg	20.4	7.62	63
Zinc	mg/kg	84.8	20.8	76
Cyanide	mg/kg	0.098	0.06	39
Ammonia nitrogen	mg/kg	278	164	41

performed annually. An average of 20 to 25 percent of the Erie Pier dredged material is removed each year and used as construction fill in projects near Duluth-Superior Harbor.

Saginaw Bay demonstration

Detroit District dredges more than 306,000 cubic meters of material annually from the 50-kilometer-long navigation channel in the Saginaw River and Bay in Michigan.

This area has also been identified as an Area of Concern, and contaminants found in the sediments include PCBs, other organics, and metals.

Concentrations in the navigation channel are not toxic or hazardous according to regulatory definitions, although there may be some small areas that fall under the Toxic Substances Control Act (TSCA) regulatory limit of greater than 50 milligrams/kilogram PCBs outside the navigation channel.

The dredged material from the navigation channel is placed in the Saginaw Bay CDF approximately 1.5 kilometers offshore in Saginaw Bay.

The Saginaw River and Bay was one of five sites given priority under the U.S. Environmental Protection Agency's (USEPA) Assessment and Remediation of Contaminated Sediments Program to evaluate new and innovative technologies.

During fall 1991 and spring 1992, the USEPA conducted a pilot-scale demonstration of dredged material washing at the Saginaw Bay CDF (Detroit District). The demonstration employed a variety of devices from the mineral processing industry to achieve separation of the fine and coarse sediment fractions (USEPA 1994).

The Saginaw demonstration was conducted on freshly dredged sediments containing more than 70 percent sand. To avoid generating a discharge stream exceeding the TSCA regulatory limit in the concentrated fines, bulk sediment having PCB concentrations in the 1- to 4-milligram/kilogram range was selected for the demonstration. Sediments were dredged by clamshell and off-loaded to a staging area at the facility by crane.

A barge-mounted mobile pilot unit, operated at a feed rate of 5 tons (4,536 kilograms) per hour, was supplied by Bergmann USA for the study. The pilot plant incorporated a grizzly and log roller to screen and delump the dredged material prior to feeding it into a rotary trommel.

Material smaller than 6 mm was processed through a hydrocyclone to separate fines from sand. The fines were then processed through a rotary screen and the coarse materials through a dense media separator to remove organics. The sand was polished in a series of hydrocyclones prior to dewatering, and the fines were processed through a clarifier (Figure 2).

Physical and chemical parameters were monitored at several points to evaluate the effectiveness of individual unit operations. These results are discussed extensively in the USEPA (1994) report.

Overall system performance was favorable, as described in Table 2. Approximately 80 percent of the dredged material was recovered as a washed product.

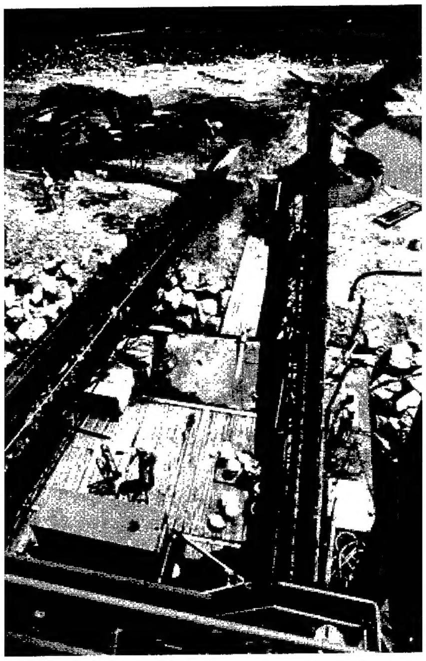

Figure 2. Saginaw River physical separation operation

Evaluating technical feasibility of dredged material recovery

Contaminants typically associate primarily with the fine and organic sediment fractions. Therefore, sediments that are predominantly coarse-grained have the highest potential for beneficial uses.

If dredged material recovery is being contemplated as part of the dredging process, the results of monitoring in the navigation channel can help managers identify those areas of the harbor with the highest potential for recovery.

Areas of the harbor that contain coarse material can be identified for separate handling. At a later date, this material can be stockpiled for use without additional testing. If the recovery is contemplated after the dredged material has been placed within the CDF (CDF mining), a sampling project in the CDF may be necessary to identify the quantities and locations of suitable material.

Coarse material typically settles rapidly, so areas of the CDF close to the discharge pipeline may contain coarse material that can be excavated without extensive testing.

If direct dredged material recovery does not appear feasible, due either to the contaminant concentrations or the amount of fine material, then separation techniques can be considered.

Particle size distribution and contaminant distribution with respect to particle size are important parameters to be evaluated in a preliminary feasibility study. These characteristics help evaluate the potential for separation and the suitability of the material to the physical and chemical requirements of the intended application.

The characteristics of an uncontaminated fraction and a contaminated fraction must be identified to select the separation technology. Particle size and density separation are the two most common separation techniques. Surface chemistry differences might also be employed, but this technology (flotation) is not yet well developed for this application.

Table 2. Characteristics of Dredged Sediment and Washed Materials at Saginaw Bay CDF

Parameter Measured	Units	Dredged Material	Washed Material
Grain size distribution >75 µm	%	76	94
PCBs	mg/kg	1.2	0.21
Cadmium	mg/kg	0.5	0.06
Chromium	mg/kg	23.9	10.8
Copper	mg/kg	17.9	6.30
Mercury	mg/kg	0.061	0.008
Nickel	mg/kg	11.5	3.3
Lead	mg/kg	20.4	7.42
Zinc	mg/kg	96.1	17.7

Economic evaluation of soil washing

The economic evaluation of sediment recovery techniques must employ a long-term perspective. A simple "per cubic meter" comparison of costs for disposal of material in existing facilities constructed in the late 1970s or early 1980s versus the cost to conduct physical separation on the same sediment volume does not reflect the actual benefits of physical separation.

In most harbors, property for construction of new CDFs is simply not available. Remaining shallow-water areas are typically wetland or other fish spawning habitat. Nearshore property is already developed or proves to be cost prohibitive.

The cost for construction of a new CDF in Duluth-Superior Harbor is predicted to be around $13.08 per cubic meter, as compared to less than about $2.60 per cubic meter in the existing Erie Pier facility. Even where adequate storage is presently available, an economic incentive for sediment washing may exist.

In addition to the CDF placement costs discussed above, an economic evaluation of the feasibility of washing should consider a number of other factors, summarized in Table 3.

Evaluating a CDF for reclamation potential

A detailed procedure for evaluating the "mining" potential of a CDF has not been established, but one approach would be to gather information about the sources of dredged material and the physical and chemical characteristics at the time of placement.

Dredging logs and sediment monitoring activities should provide an indication of the nature of the material in specific areas of the harbor. Operations personnel can also provide information about the locations of discharge pipelines and the manner in which the CDF has historically been operated. This information can be employed to develop a sampling plan that targets specific areas of the CDF.

Selection of analytes would involve an evaluation and qualitative weighting of the following factors:

- Information on current and historical industrial activities in the area.
- Material requirements (chemical and physical) for the intended beneficial use.
- Concerns identified in coordination with other agencies with respect to especially toxic or mobile contaminants.
- Representative behavior of the contaminant (an indicator of the presence, mobility, or form of other contaminants).
- Analytical costs.
- A combination of any of the previous five factors. For example, a representative contaminant with low analytical cost might be selected in preliminary analysis over a target contaminant of concern with high analytical cost.

Table 3. Economic Considerations for Soil Washing Process

Volume reduction	The contaminant distribution must be such that significant reduction in volume of the sediment to be disposed to a CDF can be achieved.
Equipment costs	The required complexity of the washing process will affect the feasibility of the project.
Equipment transportation costs	If specialized equipment is required, the costs to transport it from other regions may affect the feasibility. At the Duluth-Superior Harbor, the contractor is able to accomplish the work with readily available equipment such as front-end loaders and cranes, thereby reducing project costs.
Beneficial uses	Beneficial uses other than construction fill may exist. This alternative should be explored, and the location, demand, and material requirements determined.
Material transportation costs	The cost to transport the washed/mined material to areas where it will be used will affect the market price.
Monitoring costs	State authorities should be consulted on the testing requirements for fill material, or other applications.
Market price for fill material	Local construction firms can be consulted on the amount and specifications for road/construction fill, and their anticipated needs, as one example. In locations where sand content of dredged material is high, however, there may be competing commercial sources of sand in the area.
Dewatering costs	If a design calls for removing fine-grained material from the CDF immediately after washing, the plans will need to include belt filter presses, or other dewatering equipment.
Economic/technical advantages of washing during dredging versus CDF mining *versus* Economic/technical advantages of CDF mining	Advantages of washing at the time of dredging include the following: • Rehandling is reduced. • Work can be consolidated under one contract. • Dredged material may already be slurried. Advantages of CDF mining include the following: • Material can be selectively chosen from areas of the CDF, based on desirable characteristics. • Interdependence of dredging and washing operations is eliminated. • Physical separation equipment can be operated at optimal capacity.
Disposal options for concentrated material	Fines and organics separated from coarse material will have higher contaminant concentrations than the raw dredged material, and may require more restrictive handling or disposal. This may be a critical factor to consider in determining the feasibility of volume-reduction techniques.

Based on these considerations, the sediments would be analyzed to determine contaminant distribution. A plan and treatment train for recovery of the dredged material would be proposed if the results of the analyses indicate sufficient deposits of clean dredged material for economic justification, and bench-scale testing demonstrates that clean fractions can be separated using available physical separation technologies.

Future research needs

Current Corps policy calls for the development of Dredged Material Management Plans which identify specific measures necessary to manage the volume of material likely to be dredged from both construction and maintenance dredging of Federal harbor projects over a 20-year period. These studies must include an assessment of potential beneficial uses of the dredged material.

Trends in the Great Lakes suggest significant declines in sediment contaminant concentrations. Extrapolating those declines over the next 10 years suggests that most harbors will have sediments suitable for unconfined disposal.

Therefore, research on CDF design should be focused toward the development of transfer facilities that allow for treatment, dewatering, *and removal* of the dredged material.

Beneficial re-use is limited at island CDFs by the cost of transporting equipment to the CDF and transporting the recovered material to shore. However, if in-water beneficial uses are contemplated (that is, island creation, shallow-water habitat), this alternative may be acceptable.

It would be useful to select several candidate sites at which to study the distribution of particle sizes and contaminants within the CDF. (Some work is being done in this area by Detroit District.)

This information could be used to identify design modifications to CDFs for optimizing particle separation (reducing or eliminating the need for secondary processing).

For example, facilities could be constructed with cells to allow easier separation, classification, and dewatering of dredged material. A separate cell within the CDF specifically for dewatering and stockpiling of clean material would allow for easier separation of this material.

Also, a protocol for evaluating existing CDFs for dredged material recovery could be developed that optimizes the information produced with finite sampling and analytical resources based on expected contaminant and particle size distribution within the CDF and anecdotal site information.

The economics of volume reduction should be more extensively evaluated and guidelines developed to correlate dredged material characteristics, storage costs, and revenue production in determining the feasibility of physical separation as a volume-reduction alternative.

References

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Calendar of dredging-related events

October 9-11, 1996	**U.S. Section, Permanent International Association of Navigation Congresses, 1996 National Conference,** Seattle, WA, **POC:** Office, U.S. Section, PIANC, (703) 428-6286
November 6-8, 1996	**Western Dredging Association, Pacific Chapter, Annual Meeting** ("Innovative Technology for Environmental Protection and Enhancement in Dredging"), Honolulu, HI, **POC:** Stephen Perkins, (503) 326-3153
November 13-14, 1996	**Workshop on In Situ Capping of Contaminated Sediments,** Chicago, IL, sponsored by USEPA Great Lakes National Program Office and South/Southwest Hazardous Substances Research Center, **POC:** Jan Miller, (312) 353-6354 [Jan.A.Miller@usace.army.mil]
November 17-21, 1996	**Society of Environmental Toxicology and Chemistry Annual Conference,** Washington, DC, **POC:** SETAC, (904) 469-1500 [setac@setac.org]